Increasing Returns and Economic Prosperity: How Can Size Not Matter?*

***VERY PRELIMINARY ***

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Abstract

Models that feature ideas inevitably lead to scale effects, and this results in the counterfactual implication that larger countries should be richer than smaller ones. Perhaps small countries are not poor because they benefit from foreign ideas through trade. Quantitative trade models do imply that small countries gain more from trade than large countries, but the difference is too small to make a difference. There are two candidates to solve the puzzle: first, there are additional ways besides trade through which countries are integrated to the rest of the world, and second, countries are not fully integrated domestically. In this paper we explore these two ideas by building a quantitative model of trade and multinational production with frictions to the domestic movement of goods and ideas. The resulting model comes close to solving the puzzle, but not fully.

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1 Introduction

Models that feature ideas inevitably lead to scale effects. As Romer (1990, 1993), Jones (2005) and Jones and Romer (2010) have emphasized, this is a direct result of the fact that ideas are non-rivalrous. In growth models such as Jones (1995) and Kortum (2007), for example, idea-based scale effect imply that larger countries exhibit higher productivity. This is clearly a counter-factual implication: small countries are not poor compared to larger countries (Rose, 2006).

One possible fix is to allow for the fact that small countries trade more – perhaps small countries are not poor because they benefit from foreign ideas through trade. Quantitative trade models such as Eaton and Kortum (2002), Alvarez and Lucas (2007) and Waugh (2010) offer a simple way to explore this idea. In these models the gains from trade can be computed using aggregate trade flows and a couple of parameters that are relatively easy to calibrate. The finding is that small countries do gain more from trade than large countries, but the difference is small. Thus, even allowing for trade, quantitative models featuring ideas generate the counterfactual implication that small countries are poor. For example, if the stock of ideas is proportional to population, the Alvarez and Lucas (2007) model implies that Denmark's real GDP per capita should be 37% of the US level, whereas Denmark's actual relative real per-capita income is 91%. We refer to this as the "Danish Puzzle," but it is a puzzle common to all small countries.

There are two obvious candidates to solve this puzzle. First, there are additional ways in which countries are integrated to the rest of the world. Trade is clearly an important channel through which countries share ideas, but it is not the only one: multinational production and other forms of diffusion allow ideas originated in one country to be used directly in production in other countries (Ramondo and Rodriguez-Clare, 2010). Second, countries are not fully integrated units: the United States is not a single economy that happens to be fifty times larger than Denmark, but rather a collection of separate economies.

In this paper we explore these two ideas by building a model of trade and multinational production that builds on the ideas of Kortum (2007), Eaton and Kortum (2002), and Ramondo and Rodriguez-Clare (2010), and add frictions to the domestic movement of goods and ideas that imply that countries are not fully integrated units. We calibrate the model and explore whether openness and domestic frictions offer a resolution to the Danish Puzzle. Our main finding is that these two features do indeed help to solve the puzzle, but not fully. Returning to the case of Denmark, our calibrated model implies a relative real per-capita income of 78%, not quite reaching the one observed in the data. We also find that domestic frictions are quantitatively much more important than openness, although our calibration of domestic frictions is more tentative. We conclude by exploring the role of diffusion that takes place without being recorded in the data as multinational production.

2 The Model

We extend Ramondo and Rodriguez-Clare (2010)'s model of trade and MP to incorporate domestic trade and MP costs. The model is Ricardian with a continuum of tradable intermediate and non-tradable final goods, produced under constant returns to scale. We adopt the probabilistic representation of technologies as first introduced by Eaton and Kortum (2002). We embed the model into a general equilibrium framework similar to the one in Alvarez and Lucas (2007).

2.1 The Closed Economy

Consider first a closed economy formed by a set of identical towns, $m = 1, ..., M$, each with population $\bar{L}$. The total population is then $L = \bar{L}M$. We use subscript m to denote variables associated with town m and superscripts f and g to denote variables associated to final and intermediate goods, respectively. A representative agent in town m consumes a continuum of final goods indexed by $u \in [0,1]$ in quantities $q^f_m(u)$. Preferences over final goods are CES with elasticity $\sigma^f > 0$.

Final goods are produced with labor and a continuum of intermediate goods indexed by $v \in [0,1]$. Intermediate goods used in quantities $q^g_m(v)$ are aggregated into a *composite intermediate good* via a CES production function with elasticity $\sigma^g > 0$. We henceforth assume $\sigma^g = \sigma^f = \sigma$. Denoting the total quantity produced of the composite intermediate good in town m as Q_m, we have

$$Q_m = \left(\int_0^1 q^g_m(v)^{(\sigma-1)/\sigma} dv \right)^{\sigma/(\sigma-1)}.$$

The composite intermediate good and labor are used to produce final goods via Cobb-Douglas technologies with varying productivities across goods and towns,

$$\widetilde{q}^f_m(u) = z^f_m(u) L^f_m(u)^\alpha Q^f_m(u)^{1-\alpha}. \tag{1}$$

Here $\widetilde{q}^f_m(u)$ denotes the quantity produced of final good u in town m – we use a "tilda" over q to differentiate production, $\widetilde{q}^f_m(u)$, from consumption, $q^f_m(u)$. The variables $L^f_m(u)$ and $Q^f_m(u)$ denote the quantity of labor and the composite intermediate good, respectively, used in the production of final good u in town m, and $z^f_m(u)$ is a productivity parameter for good u in town m. Similarly, intermediate goods in town m are produced according to

$$\widetilde{q}^g_m(v) = z^g_m(v) L^g_m(v)^\beta Q^g_m(v)^{1-\beta}. \tag{2}$$

Resource constraints (at the town level) are

$$\begin{aligned} \int_0^1 L^f_m(u)du + \int_0^1 L^g_m(v)dv &= \bar{L}, \\ \int_0^1 Q^f_m(u)du + \int_0^1 Q^g_m(v)dv &= Q_m. \end{aligned}$$

Here we have assumed that labor is immobile and the composite intermediate good is non-tradable across towns, but this is innocuous since towns are identical.

Final goods are non-tradable (even across towns within a country), but intermediate goods can be traded across towns with iceberg-type trade costs $d \geq 1$ (there is no trade cost if the good is sold in the same town where it is produced). The assumption that final goods are non-tradable implies that $\widetilde{q}_m^f(u) = q_m^f(u)$ while the possibility of trade in intermediate goods implies that we can have $\widetilde{q}_m^g(v) \neq q_m^g(v)$.

There are L technologies for each good (one technology per person), and each of these technologies is freely available to producers engaging in perfect competition. Each technology is characterized by a productivity parameter z and a "home town" m. If technology (z, m) is used to produce outside of its home town (i.e., in town $s \neq m$), then there is an iceberg-type efficiency loss $h^f \geq 1$ for final goods and $h^g \geq 1$ for intermediate goods, and the effective productivity is z/h^f and z/h^g, while if the technology is used to produce in its home town (i.e., in town m) then the effective productivity is z. With a slight abuse of terminology, we will say that if a technology is used for production outside of its home town then there is "multinational production" or MP. We assume that the cost of MP for intermediate goods is higher than the cost of trade, i.e., $h^g > d$.

For each good, the L technologies are uniformly assigned to the M towns as home towns – that is, for each good, the number of technologies (i.e., $\bar{L} = L/M$) for which a particular town is the home town is the same as the number of technologies for which any other town is the home town.[1] We assume that z is drawn from a Fréchet distribution with parameters $\bar{T}$ and $\theta > \max\{1, \sigma - 1\}$, $F(z) = \exp\left(-\bar{T} z^{-\theta}\right)$, for $z > 0$.

[1]Technically, the number of ideas should be a nonnegative integer. This would require that $\bar{L}$ be an integer. To simplify the analysis we henceforth ignore this integer constraint.

2.1.1 Equilibrium Analysis

To describe the competitive equilibrium for this economy it is convenient to introduce the notion of an *input bundle for the production of final goods*, and an *input bundle for the production of intermediate goods*, both of which are produced via Cobb-Douglas production functions with labor and the composite intermediate good, and used to produce final and intermediate goods, as specified in (1) and (2), respectively. The unit cost of the input bundle for final goods is $c^f = Aw^{\alpha}(P^g)^{1-\alpha}$, and the unit cost of the input bundle for intermediate goods is $c^g = Bw^{\beta}(P^g)^{1-\beta}$, where w and P^g are the wage and the price of the composite intermediate good, respectively, and A and B are constants that depend on α and β, respectively. Letting $p_m^g(v)$ denote the price of intermediate good v, then $P^g = \left(\int_0^1 p_m^g(v)^{1-\sigma}dv\right)^{1/(1-\sigma)}$. Notice that since towns are identical, there is no need to differentiate aggregate variables (e.g., wages, price indices, unit costs) across towns.

The characterization of the equilibrium follows closely the analysis in Eaton and Kortum (2002) and Alvarez and Lucas (2007). Let $z_m^f(u)$ be the highest productivity among the set of technologies for final good u with home town m and let $z_m^g(v)$ be the highest productivity among the set of technologies for intermediate good v with home town m. Since each town is the home town for $\bar{L}$ technologies with scale parameter $\bar{T}$, by the properties of the Fréchet distribution, $z_m^f(u)$ and $z_m^g(v)$ are both distributed Fréchet with parameters $T \equiv \bar{L}\bar{T}$ and θ.

The unit cost of a final good u in town m produced with a technology with home town s is $h^f c^f / z_s^f(u)$ if $s \neq m$, and $c^f / z_m^f(u)$ if $s = m$. In a competitive equilibrium the price of the final good u in town m is simply the minimum unit cost at which this good can be obtained,

$$p_m^f(u) = \min(c^f / z_m^f(u), \min_{s \neq m}(h^f c^f / z_s^f(u)))$$

The unit cost of an intermediate good v in town m produced in town k with a technology with home town s is $dh^g c^g / z_s^g(v)$ if $m \neq k \neq s$, $dc^g / z_s^g(v)$ if $m \neq k = s$, $h^g c^g / z_s^g(v)$ if $m = k \neq s$, and $c^g / z_s^g(v)$ if $m = k = s$. Our assumption that $d < h^g$ implies that an intermediate good used in town m is either produced with the local technology, which entails unit cost $c^g / z_m^g(v)$, or it is imported from some other town s, which entails unit cost $dc^g / z_s^g(v)$.[2] Thus, the price of an intermediate good v in town m is

$$p_m^g(v) = \min\left(c^g / z_m^g(v), \min_{s \neq m}(dc^g / z_s^g(v))\right)$$

Note that since final goods are non-tradable and $d < h^g$ then there is MP but no trade in final goods and trade but no MP in intermediate goods.

Combining these results with the assumption that productivities are independently drawn from the Fréchet distribution and following standard procedures as in Eaton and Kortum (2002) and Alvarez and Lucas (2007), we can easily show that the price index for final and intermediate goods is given by

$$P^f = \gamma c^f \left(MT + (M-1)T\left(h^f\right)^{-\theta}\right)^{-1/\theta} \tag{3}$$

and

$$P^g = \gamma c^g \left(MT + (M-1)Td^{-\theta}\right)^{-1/\theta}, \tag{4}$$

respectively, where γ is a positive constant. Intuitively, the term $MT + (M-1)T\left(h^f\right)^{-\theta}$ can be understood as the number of technologies for each final good available in town m', where the $(M-1)T$ technologies with home towns $m \neq m'$ are "discounted" by $\left(h^f\right)^{-\theta}$. Similarly, the term $MT + (M-1)Td^{-\theta}$ is the number of technologies available for each intermediate good in town m', where the $(M-1)T$ technologies with home towns $m \neq m'$

[2] To see this, note that $d, h^g \geq 1$ implies that if town m is using an intermediate good produced with a technology with home town s, then the only two options that could make sense are that the good is produced in m, i.e., $k = m$, or that it is produced in s, i.e., $k = s$. Thus, if $s \neq m$, there are two relevant options, local production with an outside technology at cost $h^g c^g / z_s^f(v)$, or importing the good at cost $dc^g / z_s^f(v)$. The assumption $d < h^g$ implies that if $s \neq m$ then producing the good in town s, i.e., $k = s$, is the best option.

are "discounted" by $d^{-\theta}$.

Using $c^f = Aw^{\alpha}(P^g)^{1-\alpha}$, and $c^g = Bw^{\beta}(P^g)^{1-\beta}$, and letting $\eta \equiv (1-\alpha)/\beta$, $H \equiv 1/M + ((M-1)/M)\left(h^f\right)^{-\theta}$, and $D \equiv 1/M + ((M-1)/M)d^{-\theta}$, the equilibrium real wage is then given by

$$\frac{w}{P^f} = \tilde{\gamma} T^{(1+\eta)/\theta} \left(MH\right)^{1/\theta} \left(MD\right)^{\eta/\theta}, \tag{5}$$

where $\tilde{\gamma} \equiv (\gamma^{1+\eta}AB^{\eta})^{-1}$. When towns are in isolation (i.e., $d, h \to \infty$), then $D = H = 1/M$, so the real wage is $\gamma T^{(1+\eta)/\theta}$. As d and h^f decrease towards 1, D and H increase and the real wage increases as towns get access to technologies from other towns either through trade (for the case of intermediate goods) or through MP (for the case of final goods). The term $(MH)^{1/\theta}$captures the gains from MP in final goods while the term $(MD)^{\eta/\theta}$ captures the gains from trade in intermediate goods. In the limit, when there are no trade or MP costs, i.e., $d = h^f = 1$, then $D = H = 1$ and the real wage is $\gamma(MT)^{(1+\eta)/\theta}$.

There are two implications of these results: first, larger countries will exhibit higher real income levels. This is due to aggregate economies of scale as semi-endogenous growth models (see Ramondo and Rodríguez-Clare, 2010). Second, higher trade and MP costs (reflected in lower D and H) diminish the strength of these economies of scale. This will play an important role below.

2.2 The World Economy

Now consider a set of countries indexed by $n \in \{1, ..., N\}$ with preferences and technologies as described above. As with the case of the closed economy above, each country is formed by set of identical towns, each with population $\bar{L}$. The number of towns in country n is M_n, so that the population size of country n is $L_n = \bar{L}M_n$.

Intermediate goods are tradable across towns within a country and across towns in different countries, but final goods are not. International trade is subject to iceberg-type costs: $d_{nl} \geq 1$ units of any good must be shipped from any town in country l for one unit to arrive in any town in country n. We assume that domestic trade is also subject to an iceberg-type cost: $d_{nn} \geq 1$ units of any good must be shipped from a town k in country n for one unit to arrive in a town s also in country n. Trade within a town is costless. We also assume that the triangular inequality holds: $d_{nl} \leq d_{nj}d_{jl}$ for all n, l, j.

Each technology has a country of origin, but it can be used also in other countries as well. As mentioned above, when a technology from country i is used for production in country $l \neq i$ we say that there is "multinational production" or simply MP. We adopt the convention that the subscript n denotes the destination country, subscript l denotes the country of production, and subscript i denotes the country where the technology originates.

There are L_i technologies for each good in country i. Each technology is characterized by three elements: first, the country i from which it originates, second, a vector that specifies the technology's productivity parameter in each country, $\boldsymbol{z} = (z_1, ..., z_N)$, and third, a vector that specifies the technology's "home town" in each country, $\boldsymbol{m} = (m_1, ..., m_N)$.

Using a technology originating in country i for production in country i but outside of the technology's home town (in country i) entails an iceberg-type efficiency loss or "MP cost" of $h_{ii} \geq 1$. Moreover, using a technology originated in country i in the technology's home town in country $l \neq i$ entails an MP cost of $h^f_{li} \geq 1$ for final goods and $h^g_{li} \geq 1$ for intermediates. Finally, the total MP cost associated with using a technology from country i in country $l \neq i$ outside of the technology's home town in country l is $h^f_{li}h^f_{ii}$ for final goods and $h^g_{li}h^g_{ii}$ for intermediate goods. These assumptions imply that the effective productivity of a technology $(\boldsymbol{z}, \boldsymbol{m})$ originated in country i used in the technology's home town in country $l \neq i$ is z_l/h^f_{li} or z_l/h^g_{li} while if they are used in country $l \neq i$ but outside of the technology's home town then the effective productivity is $z_l/h^f_{li}h^f_{ll}$ or $z_l/h^g_{li}h^g_{ll}$ We assume that $d_{ii} \leq h^g_{ii}$, so in equilibrium technologies to produce intermediate goods will always be used in their home town.

We assume that technologies are uniformly assigned to home towns in each country, i.e., for each good and each country i, the number of technologies from i for which the home town in country l is town m is the same as the number of technologies from i for which the home town in country l is town m'.[3] To clarify: there are L_i technologies for each good in each country (not in each town), and the number of technologies from any country i for which a particular town in country n is the home town is L_i/M_n.

Finally, we assume that each productivity z_l for technologies originating in country i is independently drawn from the Fréchet distribution with parameters $\bar{T}_i$ and θ.

2.3 Equilibrium Analysis

We let $z^f_{m,ni}(u)$ be the highest productivity among the set of technologies for final good u originating in country i with home town m in country n, and let $z^g_{m,ni}(v)$ be the highest productivity among the set of technologies for intermediate good v originating in country i with home town m in country n. Also, let $z^g_{li}(v) = \max_m z^g_{m,li}(v)$. By the properties of the Fréchet distribution, $z^f_{m,ni}(u)$ and $z^g_{m,ni}(v)$ are distributed Fréchet with parameters $L_i\bar{T}_i/M_n$ and θ. Finally, let c^f_l and c^g_l denote the unit costs of the input bundle for final and intermediate goods in country l, respectively.

Price indices. Following a similar logic as in the equilibrium analysis of a closed economy, we can show (see Appendix for details) that the price index of final goods is

$$\gamma^\theta \left(P^f_n\right)^{-\theta} = M_n T_n (c^f_n)^{-\theta} H_n + \sum_{i \neq n} M_i T_i (h_{ni} c^f_n)^{-\theta} H_n, \tag{6}$$

while the price index of intermediates is

[3]One interpretation of this assumption is as follows. First, recall that, for each good, the number of technologies in a country is the same as the number of people. Thus, we can link each technology to a person. Second, imagine that each person has a randomly assigned "friend" in every country. We can then assume that a technology's home town in country l for the technology linked to person X in country i is the town where X's friend resides in country l.

$$
\begin{aligned}
\gamma^{\theta}\left(P_n^g\right)^{-\theta} &= M_n T_n (c_n^g)^{-\theta} D_n + \sum_{i\neq n, l=n} M_i T_i (h_{ni} c_n^g)^{-\theta} D_n \\
&+ \sum_{i\neq n, l=i} M_i T_i (d_{ni} c_i^g)^{-\theta} + \sum_{l\neq n, l\neq i} M_i T_i \left(d_{nl} h_{li} c_l^g\right)^{-\theta},
\end{aligned} \tag{7}
$$

where $T_i \equiv \bar{L}\bar{T}_i$, $H_n \equiv 1/M_n + ((M_n-1)/M_n)\left(h_{nn}^f\right)^{-\theta}$ and $D_n \equiv 1/M_n + ((M_n-1)/M_n) d_{nn}^{-\theta}$. In the case of final goods, the first term on the RHS of (6) corresponds to technologies originating in country n while the second term corresponds to technologies originating in country $i \neq n$. In the case of intermediate goods, the first term on the RHS corresponds to technologies originating in country n, the second term corresponds to technologies originating in country $i \neq n$ but used to produce domestically in country n, the third term corresponds to technologies originating in country $i \neq n$ used to produce in country i and export to country n, and the final term corresponds to technologies from any country used to produce outside of country n and outside of the country where the technology originates.

Trade flows. Examining the contribution of country l to the price index for intermediates in n reveals the value of trade flows (exports) from all towns in country $l \neq n$. This is given by

$$
X_{nl} = \left(\gamma P_n^g / c_l^g\right)^{\theta} d_{nl}^{-\theta} \left[\sum_{i\neq l} M_i T_i \left(h_{li}^g\right)^{-\theta} + M_l T_l\right] \eta w_n L_n. \tag{8}
$$

where $X_n^g = \eta w_n L_n$ is the expenditure on intermediate goods in country n. In turn, domestic trade flows are

$$
X_{nn} = \left(\gamma P_n^g / c_n^g\right)^{\theta} D_n \left[\sum_{i\neq n} M_i T_i \left(h_{ni}^g\right)^{-\theta} + M_n T_n\right] \eta w_n L_n. \tag{9}
$$

For future reference, note that, using (8) and the equivalent of (9) for X_{ll}, the gravity equation is

$$\frac{X_{nl}/w_n L_n}{X_{ll}/w_l L_l} = D_l^{-1} \times \left(d_{nl} \frac{P_l^g}{P_n^g} \right)^{-\theta}. \tag{10}$$

The term D_l^{-1} is a country specific effect greater than one. When $d_{ll} = 1$, $D_l = 1$ and (10) collapses to the gravity expression in Eaton and Kortum (2002).

MP Flows. Again, examining the price index for intermediate goods reveals that total MP in intermediate goods by country i in $l \neq i$ is

$$Y_{li}^g = M_i T_i \left(c_l^g h_{li}^g\right)^{-\theta} \left[D_l \frac{\eta w_l L_l}{\left(\gamma P_l^g\right)^{-\theta}} + \sum_{n \neq l} d_{nl}^{-\theta} \frac{\eta w_n L_n}{\left(\gamma P_n^g\right)^{-\theta}} \right], \tag{11}$$

while total production in country n with domestic technologies is

$$Y_{nn}^g = M_n T_n (c_n^g)^{-\theta} \left[D_n \frac{\eta w_n L_n}{\left(\gamma P_n^g\right)^{-\theta}} + \sum_{j \neq n} d_{jn}^{-\theta} \frac{\eta w_j L_j}{\left(\gamma P_j^g\right)^{-\theta}} \right]. \tag{12}$$

For final goods, total MP by country i in $n \neq i$ is

$$Y_{ni}^f = M_i T_i \left(\frac{c_n^f h_{ni}^f}{\gamma P_n^f} \right)^{-\theta} H_n w_n L_n, \tag{13}$$

while total production in n with domestic technologies is

$$Y_{nn}^f = M_n T_n \left(\frac{c_n^f}{\gamma P_n^f} \right)^{-\theta} H_n w_n L_n. \tag{14}$$

When $D_{nn} = H_{nn} = 1$, Y_{ni}^g and Y_{ni}^f collapse to the expressions in Ramondo and Rodríguez-Clare (2010), except that now MP flows in both sectors are multiplied by an extra L_i. This reflects the assumption that in our model countries are a collection of towns, and not just a dot in space.

2.4 Gains from trade, MP, and openness

We define the gains from openness as the change in the real wage from a situation where countries are in isolation to a situation with trade and MP. The gains from trade are defined as the change in the real wage from a situation with only MP to a situation with trade and MP. The gains from MP are defined analogously.

The following lemma (proved in the Appendix) characterizes the real wage for each country n as a function of trade and MP flows.

Lemma 1. The real wage in country n is given by

$$\frac{w_n}{P_n^f} = \widetilde{\gamma}\left(M_n T_n\right)^{(1+\eta)/\theta} H_n^{1/\theta} D_n^{\eta/\theta} \left(\frac{Y_{nn}^f}{w_n L_n}\right)^{-1/\theta} \left(\frac{Y_{nn}^g}{\eta w_n L_n}\right)^{-\eta/\theta} \left(\frac{X_{nn}}{\eta w_n L_n}\right)^{-\eta/\theta}. \tag{15}$$

Using this result, we can easily calculate the gains from trade, MP, and openness as a function of trade and MP flows.

Proposition 1. The gains from trade, MP, and openness are given, respectively, by

$$GT_n = \left(\frac{X_{nn}}{\eta w_n L_n}\right)^{-\eta/\theta}, \tag{16}$$

$$GMP_n = \left(\frac{Y_{nn}^f}{w_n L_n}\right)^{-1/\theta} \left(\frac{Y_{nn}^g}{\eta w_n L_n}\right)^{-\eta/\theta}, \tag{17}$$

$$GO_n = GT \times GMP. \tag{18}$$

(Need to add this: These gains are the same as those in Ramondo and Rodríguez-Clare (2010) for the case with $a = \rho = 0$, but note this: GMP_n is not really the gains from MP, see RR, although it is true that $GO_n = GT \times GMP$).

It is worth noting that the steady state growth rate for the open economy is the same as for the closed economy, given by differentiating (15) with respect to time. Growth is driven by the same forces that generate the gains from openness in the static model, namely the aggregate economies of scale associated with the fact that a larger population is linked to a higher stock of non-rival ideas. We further assume that the growth rate of population is common across countries, so that the growth of real income per capita in each country is given by (19).

3 Empirical Analysis

We consider a set of nineteen OECD countries: Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, Great Britain, Germany, Greece, Italy, Japan, Netherlands, Norway, New Zealand, Portugal, Sweden and United States. This is the same set of countries as in Eaton and Kortum (2002).

For these countries, we compute real wages in the data as real (PPP) GDP from the Penn World Tables (6.3) divided by is a measure of equipped labor from Klenow and Rodríguez-Clare (2005) that controls both for physical and human capital. The latter is also our measure of L_n. We want to compare real wages in the data with those implied by the model.

3.1 Calibration of key parameters

We need to set values for η and θ. We set the labor share in the intermediate goods' sector, β, to 0.5, and the labor share in the final sector, α, to 0.75, as calibrated by Alvarez and Lucas (2007). This implies $\eta \equiv (1-\alpha)/\beta = 0.5$.

The value of θ is critical for our exercise. We consider three approaches for this calibration. First, we calibrate θ to match the model's implication for the growth rate with that in the data. If $\bar{L}$ grows at a constant rate of $g_L > 0$ in all countries, then the model leads to a common long-run growth rate of

$$g = \frac{1+\eta}{\theta} g_L. \tag{19}$$

This follows by differentiating (5) with respect to time and then noting that $T = \bar{L}\bar{T}$ implies that $g_T = g_L$.[4] Following Jones (2002), we set g_L equal to the growth rate of research employment, which Jones calculated as 0.048. Using (19), $\eta = 0.5$, $g_L = 0.048$ and setting $g = 0.01$ (also from Jones, 2002), then $\theta = 7.2$. Jones and Romer (2010) follow this kind of reasoning and argue that $\frac{1+\eta}{\theta} = 1/4$, which implies $\theta = 6$, although they acknowledge that different interpretations of the mapping between model and data could also justify setting $\frac{1+\eta}{\theta}$ as high as 1 or 2.

Our second calibration approach is to calibrate θ by noting that our model is fully consistent with the Eaton and Kortum (2002) model of trade. Eaton and Kortum (2002) estimate values of θ between 3 and 12, with a preferred estimate of $\theta = 8$. More recent estimates using different procedures range between 3 and 8: Donaldson (2010) estimates $\theta = 3.8$; Costinot, Donaldson, and Komunjer (2011) estimate $\theta = 6.5$; Simonovska and Waugh (2011) estimate $\theta \in [2.5, 4.5]$; Caliendo and Parro (2011) estimate $\theta = 8.2$; and Arkolakis et al (2011) estimate $\theta = 5.6$.

Finally, a third approach is to use the results of Alcala and Ciccone (2004), who show that controlling for geography (area), institutions and openness (trade), larger countries (in terms of population) have a higher real GDP per capita with an elasticity of 0.3. We interpret this result in the context of equation (15). If geography controls for H_n and D_n, institutions control for T_n, and openness controls for the last three terms on the RHS of (15), then since M_n is proportional to population, the result of a 0.3 elasticity in Alcala and Ciccone (2004) implies that $(1+\eta)/\theta = 0.3$. With $\eta = 1/2$ then this implies that $\theta = 5$.

Given these estimates, we choose $\theta = 6$ as our central value and then explore robust-

[4] Steady state growth rates are the same for all countries, and not affected by openness. This implies that the growth rate for the open economy is the same as the one for the closed economy.

ness of our results with alternative values of $\theta = 4$ and $\theta = 8$.

3.2 Preliminary results: the Danish puzzle

We start with the model of a closed economy with no domestic frictions. For that case we have $H = D = 1$ so equation (5) implies that the real wage is given by

$$\frac{w_n}{P_n^f} = \tilde{\gamma} \left(M_n T_n \right)^{(1+\eta)/\theta}. \tag{20}$$

We need an empirical measure of $M_n T_n$. We assume that $\overline{T}_n$ varies directly with the share of R&D employment observed in the data (from World Development Indicators) and then note that $M_n T_n = L_n \overline{T}_n$. Thus, our measures of L_n and $\overline{T}_n$ lead to a measure of $M_n T_n$. In Figure 3 we plot the model's implied real wage against our measure of size adjusted by R&D intensity, $L_n \overline{T}_n$, both relative to the United States. We see that the model substantially under-predicts the income level of small countries under isolation (green dots). As an example, consider Denmark. The model implies an income of 35% of the U.S. level, the relative income in the data is 91%. We refer to this as the Danish puzzle, but it is common to all the small countries in our sample. In the rest of this section we explore whether allowing for openness and domestic frictions resolves the puzzle.

3.3 Adding gains from openness

In this section we explore how much of the gap between the real wage under isolation and the one observed in the data can be explained by the gains from trade and MP. To do so, we assume that there are no domestic frictions, and then note that the real wage is the same as that in autarky plus the gains from openness. From (20) and the results of

Proposition 1, the real wage is given by

$$\frac{w_n}{P_n^f} = \tilde{\gamma}\left(M_n T_n\right)^{(1+\eta)/\theta} GO_n \tag{21}$$

where

$$GO_n = \left(\frac{X_{nn}}{\eta w_n L_n}\right)^{-\eta/\theta}\left(\frac{Y_{nn}^f}{w_n L_n}\right)^{-1/\theta}\left(\frac{Y_{nn}^g}{\eta w_n L_n}\right)^{-\eta/\theta}. \tag{22}$$

In the next subsection we explain how we compute the three terms on the RHS of the previous equation and in the subsection that follows we present the results of this exercise.

3.3.1 Trade and MP data

The gains from openness can be directly calculated using data on trade flows, MP sales, and gross manufacturing production. We use data on manufacturing trade flows from country i to country n from STAN as the empirical counterpart for trade in intermediates in the model, X_{ni}, and we think of total absorption in manufacturing (calculated as gross production minus total exports plus total imports) as the empirical counterpart of $\eta w_n L_n$ in the model.

Data on the gross value of production for multinational affiliates from i in n, from UNCTAD, is used as the empirical counterpart of bilateral MP flows in the model, $Y_{ni} \equiv Y_{ni}^f + Y_{ni}^g$. One problem is that these MP flow data is not disaggregated by sector, so we do not observe MP flows in manufacturing (Y_{ni}^g) and non-manufacturing (Y_{ni}^f) separately. We observe MP flows in manufacturing only for the United States, and there we see that such flows represent approximately one half of the total MP flows – i.e.,

$$\sum_{i \neq US} Y_{US,i}^g = \frac{1}{2}\sum_{i \neq US} Y_{US,i}.$$

This suggests using one half of the total MP flows as the empirical counterpart for Y_{ni}^g, and similarly for Y_{ni}^f. We use GDP in current dollars (from World Development Indicators) as the empirical counterpart of $w_n L_n$ in the model.

All variables in the data are averages over the period 1996-2001. Details on the MP data are in the Appendix. Table 4 in the Appendix presents the results for the domestic trade shares, $\frac{X_{nn}}{\eta w_n L_n}$, and the domestic MP shares in final and intermediate goods, $\frac{Y^f_{nn}}{w_n L_n}$ and $\frac{Y^g_{nn}}{\eta w_n L_n}$, for all the countries in our sample.

3.3.2 Does openness resolve the Danish puzzle?

Figure 1 presents the results of the gains from openness (GO_n) against our adjusted measure of size, $L_n \overline{T}_n$, relative to the United States. As expected, small countries gain much more than large countries. Does this explain the Danish puzzle?

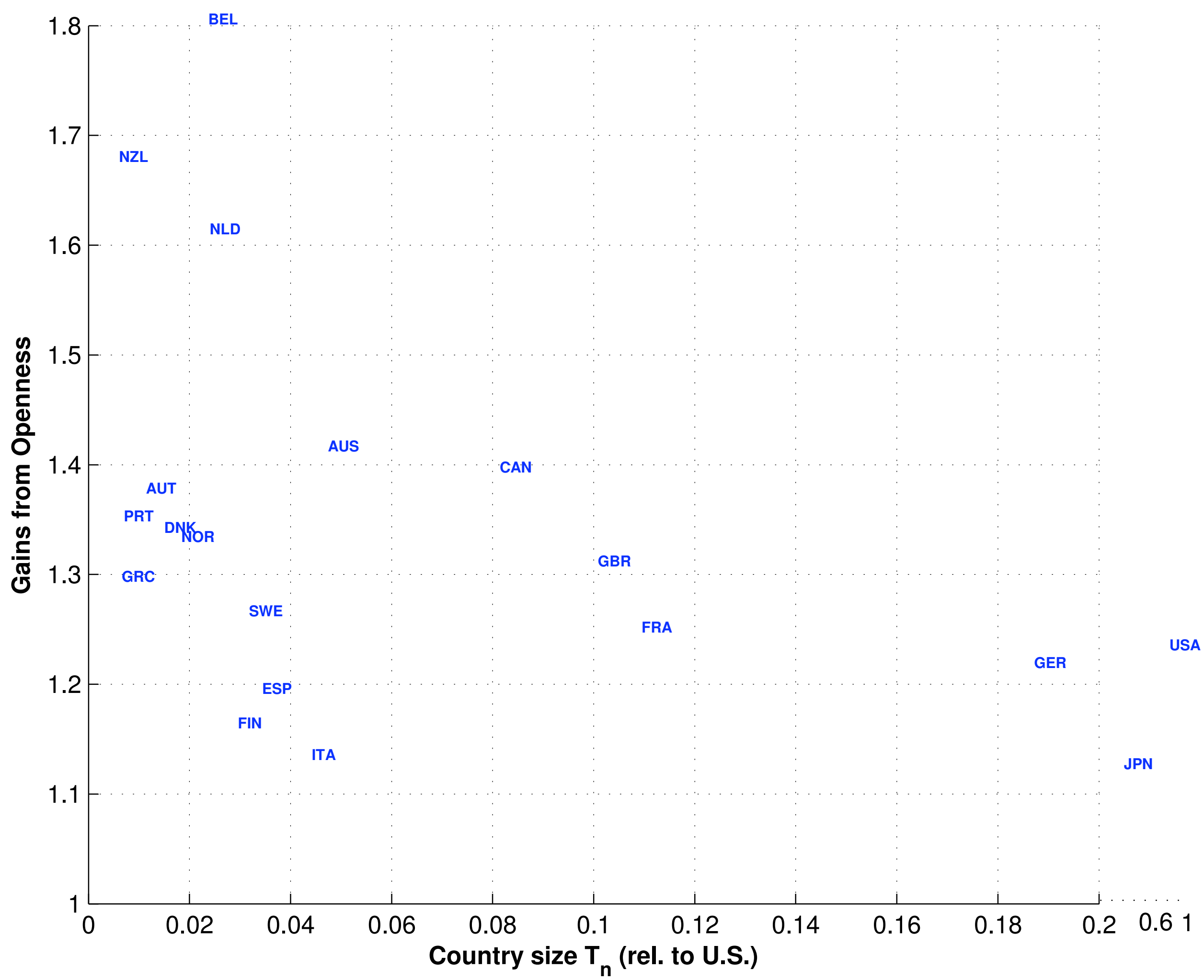
Table 1 presents the implications of our calibrated model for real wages (always relative to the United States) under isolation and openness, assuming alternatively no domestic frictions and the presence of them. We restrict our attention in this table to the seven smallest countries in our sample. Results for the rest of the countries are presented in the Appendix.

With no domestic frictions, the relative real wage for country n can be written as

$$\frac{w_n / P^f_n}{w_{US} / P^f_{US}} = \underbrace{\frac{(M_n T_n)^{(1+\eta)/\theta}}{(M_{US} T_{US})^{(1+\eta)/\theta}}}_{\text{size}} \underbrace{\frac{GO_n}{GO_{US}}}_{\text{openness}}. \tag{23}$$

The first column of Table 1 presents the real wage under isolation with no domestic frictions – this is the first term on the RHS of equation (23). As mentioned before, the model implies that small countries would be much poorer than in the data. The second column presents the real wage taking into account the gains from openness – this is the relative real wage as implied by (23).

Figure 1: Gains from Openness and Size



It is important to emphasize that all these results for real wages are relative to the United States, so column 2 is not simply column 1 multiplied by GO_n. The reason is that the United States also have gains from openness, and this is taken into account in the result of column 2. Thus, for example, the gains from openness for Denmark are 35% while for the United States these gains are 23%, so the net effect of openness in solving the Danish puzzle is not as large.

Overall, the puzzle remains significant: even taking into account the role of openness, the model still implies that Denmark would be only 38% as rich as the United States

Table 1: Calibration's results. Small countries.

	Real Wage (relative to U.S.)				
	No domestic frictions		Domestic frictions		Data
	isol.	*GO*	isol.	*GO*	
Portugal	0.29	0.31	0.59	0.64	0.92
New Zealand	0.33	0.45	0.68	0.92	0.69
Greece	0.34	0.36	0.58	0.62	0.77
Denmark	0.35	0.38	0.71	0.78	0.91
Norway	0.37	0.40	0.75	0.81	0.80
Belgium	0.42	0.61	0.73	1.06	0.99
Finland	0.41	0.39	0.84	0.80	0.82

Calibration with $\theta = 6$. Countries ordered by R&D-adjusted size $\overline{T}_i L_i$.

3.4 Adding domestic frictions

Allowing for domestic frictions and openness, real wages are given by equation (15), and hence real wage relative to the United States can be written as

$$\frac{w_n/P_n^f}{w_{US}/P_{US}^f} = \underbrace{\frac{(M_n T_n)^{(1+\eta)/\theta}}{(M_{US} T_{US})^{(1+\eta)/\theta}}}_{\text{size}} \cdot \underbrace{\frac{(H_n)^{1/\theta}(D_n)^{\eta/\theta}}{(H_{US})^{1/\theta}(D_{US})^{\eta/\theta}}}_{\text{domestic frictions}} \cdot \underbrace{\frac{GO_n}{GO_{US}}}_{\text{openness}}. \tag{24}$$

The role of domestic frictions is captured in the second term on the RHS of this expression. To proceed, we need to calibrate d_{nn} and h_{nn}^f for all countries, and also decide on the empirical counterpart of M_n.[5]

3.4.1 Calibrating domestic frictions

For the number of towns, M_n, we start by setting $M_{USA} = 51$ and fix $\bar{L} = L_{USA}/M_{USA}$, for all countries in the sample. Then, we calculate $M_n = L_n/\bar{L}$, for all $n \neq USA$, using for L_n our measure of equipped labor in the data described above. Notice that, given our calibration of M_n, the concept of a "town" is consistent across different countries.

For domestic trade cost, d_{nn}, we use data on shipments between the fifty one states

[5] Under the assumption that $h_{nn}^g > d_{nn}$, the value of h_{nn}^g has no importance.

(fifty states and the District of Columbia) of the United States from the Commodity Flow Survey, for the years 2002 and 2007. We do not observe flows between state m and each other state $k \neq m$, but we do observe the flows between m and the remaining fifty states. Let δ_{mr} be the value of shipments into state m from the remaining states, δ_{mm} the value of shipments into state m from m, and d_{mm} the trade cost to ship to state m from any other state. The model establishes that

$$d_{mm}^{-\theta} = \frac{\delta_{mr}}{\delta_{mm}\left(M_n - 1\right)}, \tag{25}$$

for $m \neq r$. Using this equation and the data on shipments between states, given a value for the parameter θ, we can easily calculate a value for d_{mm}, for each state m. Our estimate of d_{nn} for $n = USA$ is just an average of d_{mm} across states, $d_{nn} = \sum_m d_{mm}/M_n$. Table 2 reports the results of our estimation of d_{nn} for three different values of θ (4.5, 6, and 7.5). The average estimates of domestic trade costs among the United States are very similar across years. As expected, the estimate decreases with the value of θ.

Table 2: Domestic trade cost for United States: Summary statistic.

	2002			2007		
	$\theta = 4.5$	$\theta = 6$	$\theta = 7.5$	$\theta = 4.5$	$\theta = 6$	$\theta = 7.5$
Average	2.1	1.7	1.5	2.1	1.8	1.6
Standard Deviation	0.3	0.2	0.1	0.2	0.1	0.1
Maximum	2.7	2.1	1.8	2.8	2.2	1.9
Minimum	1.2	1.1	1.1	1.6	1.4	1.3

Own calculations using data from the Commodity Flow Survey for the Unites States, for 2002 and 2007.

Domestic frictions for both trade and MP are crucial variables in our empirical exercise. Here we assume that d_{nn} is the same as the one for the United States for the remaining countries in our sample. We take the estimate of d_{nn} for 2002, for $\theta = 6$ (our benchmark), $d_{nn} = 1.7$. We also assume MP frictions in final goods are as large as trade frictions in that $h_{nn}^f = d_{nn}$.

3.4.2 The role of domestic trade and MP frictions

Before we present the results, we show how h^f_{nn} and d_{nn} independently matter for our results. Figure 2 shows the relationship between these two domestic frictions and the real wage implied by the model for Denmark (relative to the United States).

The left panel of Figure 2 considers changes in d_{nn} while keeping $h^f_{nn} = 1.7$. In the data, Denmark's real wage, relative to United States, is 0.91. The real wage under isolation increases with d_{nn}: going from $d_{nn} = 1$ (no frictions) to $d_{nn} = 4$, for both Denmark and United States, reduces the gap in the real wage between the two countries from a little less than 0.6 to almost 0.8.

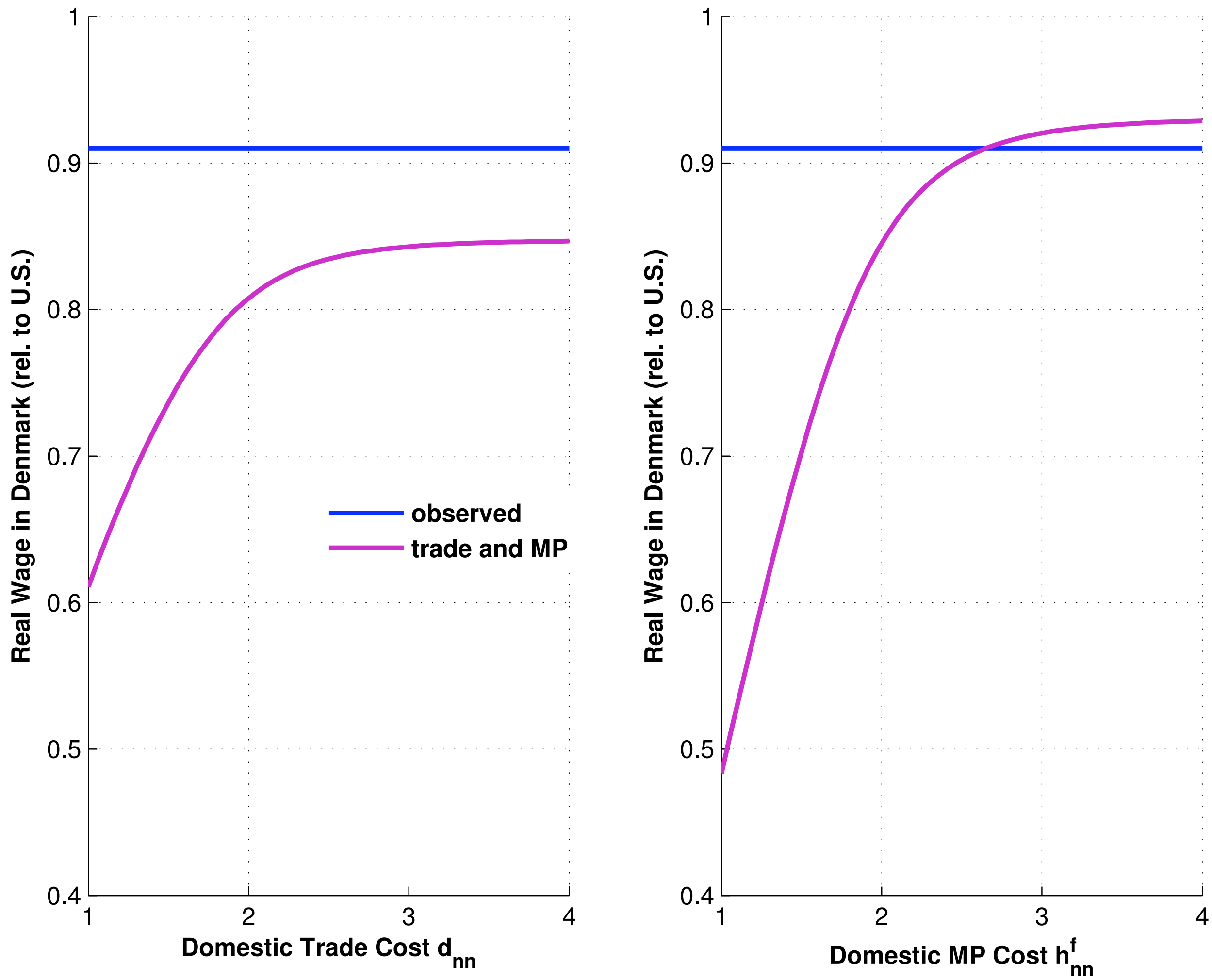
Similarly, the right panel of Figure 2 considers changes in h^f_{nn} for both Denmark and United States, while $d_{nn} = 1.7$. Results are similar to the ones coming from changing d_{nn}, but as the MP domestic frictions increase, Denmark would catch up faster with the United States. At $h^f_{nn} = 4$, this country would even overshoot the real wage gap observed in the data. Not surprisingly, higher domestic frictions in either trade or MP hurt the larger country more than the small country and so allow the smaller country to catch up.

3.4.3 Do domestic frictions explain the Danish puzzle?

In columns 4 and 5 of Table 1 we present the results for relative real wages taking into account domestic frictions as calibrated above (i.e., $d_{nn} = h^f_{nn} = 1.7$). Column 4 presents the relative real wage taking into account domestic frictions only –the first and second terms of the RHS of equation (24). Column 5 takes into account both domestic frictions and openness – all terms on the RHS of the same equation.

As expected, small countries are richer (relative to the United States) in a world with domestic frictions than without such frictions. This is just the consequence of higher domestic trade and MP costs diminishing the strength of aggregate economies of scale. For example, for Denmark, the relative real wage in isolation increases from 0.35 to 0.71 when

Figure 2: Domestic Frictions and Real Wage: the Case of Denmark

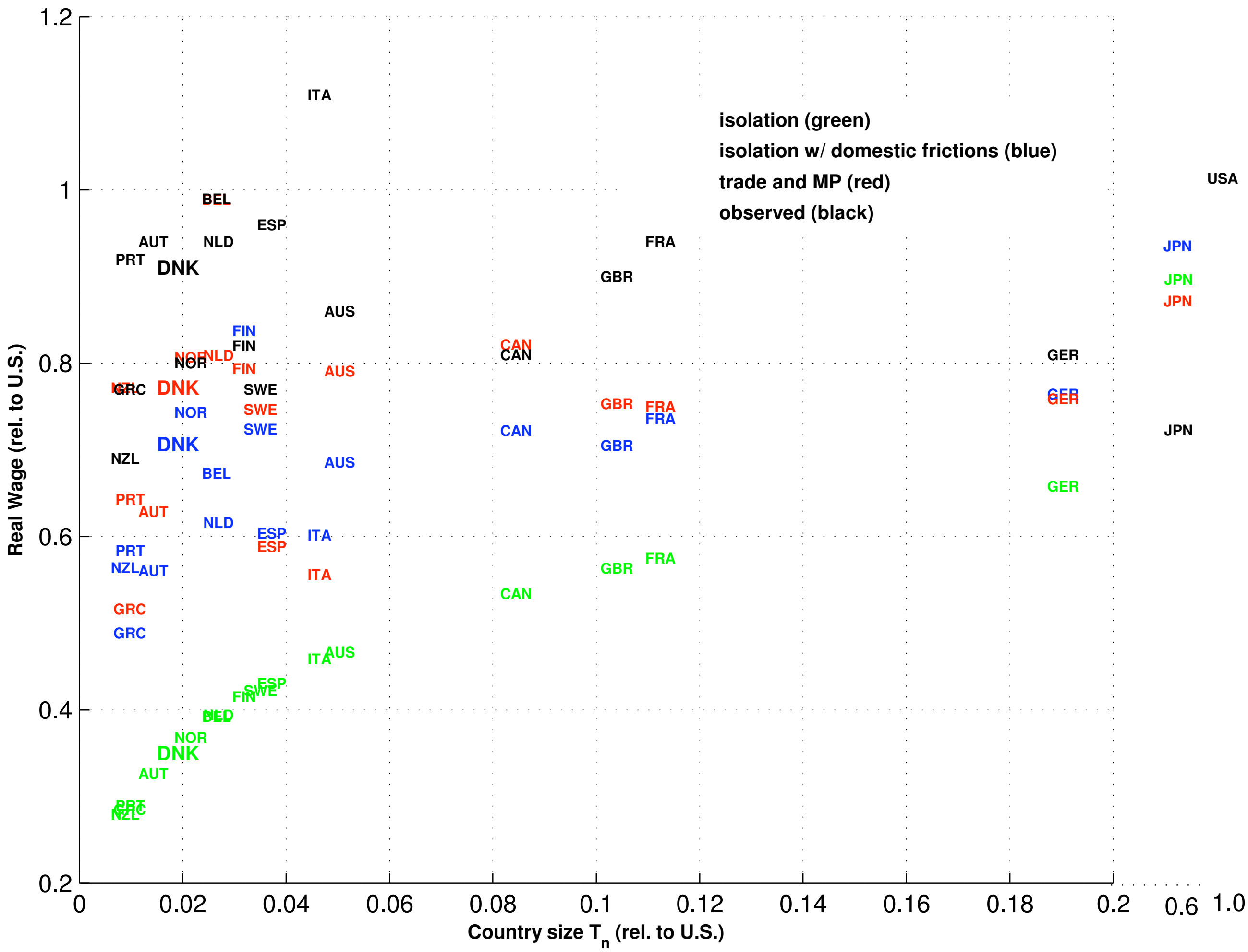


domestic frictions are considered. Perhaps more surprisingly, domestic frictions help to close the Danish puzzle much more than openness. For Denmark, domestic frictions bring the relative real wage from 0.35 to 0.71 whereas openness takes it from 0.71 to 0.78.

For most of these small countries, there is still an unexplained gap between the relative real wage in our calibrated model and in the data. Again, for Denmark, the real wage in the calibrated model is 0.78 while in the data it reaches 0.91. In contrast, for a country like New Zealand the model overestimates the observed real wage, 0.92 against 0.69.

Figure 3 shows, for the nineteen countries in the sample, the observed real wage, the calibrated real wage under isolation in a world with and without domestic frictions (as in columns 2 and 4 in Table 1), and the calibrated real wage in a world with domestic frictions as well as trade and MP flows as observed in the data (column 5 in Table 1). Countries are ordered by their R&D-adjusted size (given by $\overline{T}_i L_i$). This figure makes

Figure 3: Real Wage: observed, isolation, and openness (trade and MP).



clear that it is among small countries that we have an unexplained gap between the real wage in the data and the calibrated model. For larger countries, the calibrated model often over-predicts the real wage as a share of U.S. real wage. Again, the factors that contribute the most to close the income gap with the United States are not the gains from trade and MP, but the presence of frictions for these two flows within a country (see green against blue, and blue against red in the figure).

Finally, Table 3 illustrates how the gap between calibrated and observed real wage varies with different values of θ (and consequently, our calibrated domestic frictions, $d_{nn} = h^f_{nn}$). We present results for the eight smallest countries in our sample.

Table 3: Calibration's results for different values of θ. Small countries.

	Real Wage (relative to U.S.)								
	$\theta = 6$			$\theta = 4.5$			$\theta = 7.5$		
	$d_{nn} = 1.7$			$d_{nn} = 2.1$			$d_{nn} = 1.5$		
	isol.	d.f.	GO	isol.	d.f.	GO	isol.	d.f.	GO
Portugal	0.29	0.59	0.64	0.19	0.49	0.56	0.37	0.65	0.70
New Zealand	0.33	0.68	0.92	0.19	0.60	0.90	0.37	0.73	0.93
Greece	0.34	0.58	0.62	0.19	0.49	0.53	0.37	0.65	0.68
Denmark	0.35	0.71	0.78	0.23	0.64	0.72	0.42	0.76	0.82
Norway	0.37	0.75	0.81	0.25	0.68	0.76	0.43	0.79	0.84
Belgium	0.42	0.73	1.06	0.28	0.66	1.09	0.46	0.77	1.05
Finland	0.41	0.84	0.80	0.29	0.80	0.74	0.47	0.87	0.83

"isol." refers to the first term in the RHS of equation (24); "d.f." refers to the first plus second term of equation (24); "GO" refers to the whole RHS of equation (24).

When θ is higher and domestic frictions are re-calibrated accordingly, the real wage (relative to the U.S.) augmented by the gains from trade and MP is closest to the one observed in the data. Notice that by simultaneously changing θ and d_{nn} such that equation equation (25) is satisfied, neither H_n nor D_n are affected by changes in θ. Thus, we can easily see the effect of θ by taking logs in equation (24) and differentiating with respect to θ,

$$\frac{d \log}{d\theta} \frac{w_n/P^f_n}{w_{US}/P^f_{US}} = -\frac{1}{\theta^2}\left[(1+\eta)\log\frac{(M_n T_n)}{(M_{US}T_{US})} + \log\frac{H_n D^\eta_n}{H_{US}D^\eta_{US}} - \log\frac{\widetilde{GO}_n}{\widetilde{GO}_{US}}\right], \tag{26}$$

where $\widetilde{GO} \equiv GO^{-\theta}$. On the one hand, higher θ has a negative effect on the real wage gap through "size"and domestic frictions (the first and second term in the RHS of equation 26, respectively). That is why for all countries, the real wage relative to the United States under isolation is lower than in the open economy. On the other hand, higher θ implies larger gains from openness and hence, increases the (relative) real wage (third term in the RHS of equation 26). For small countries, the effect on gains dominates the one on size, and higher θ implies a higher real wage (relative to United States). The exception is Belgium among the seven smallest countries in our sample.

4 Global Ideas

As mentioned above, domestic frictions and openness are not enough to close the Danish puzzle. Here we explore the possible role of diffusion of ideas. There simplest way to model diffusion is to assume that a share ϕ of ideas can be used for production outside of the country from where they originated but without being recorded as MP and consequently without incurring any MP costs. Then, we can show that the relative real wage is

$$\frac{w_n/P_n^f}{w_{US}/P_{US}^f} = \underbrace{\frac{\left(\left(1-\phi\right)M_n T_n + \phi T_W\right)^{(1+\eta)/\theta}}{\left(\left(1-\phi\right)M_{US} T_{US} + \phi T_W\right)^{(1+\eta)/\theta}}}_{\text{autarky and no domestic frictions}} \cdot \underbrace{\frac{\left(H_n\right)^{1/\theta}\left(D_n\right)^{\eta/\theta}}{\left(H_{US}\right)^{1/\theta}\left(D_{US}\right)^{\eta/\theta}}}_{\text{domestic frictions}} \cdot \underbrace{\frac{GO_n}{GO_{US}}}_{\text{openness}},$$

where

$$T_W = \sum_i M_i T_i.$$

A value of $\phi = 0.025$ solves the Danish puzzle.

5 Conclusions

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A Proofs

Price indices. We now derive the price indices for final and intermediate goods in the open economy. Consider first the case of final goods. What are the different technologies available for town m in country n in consuming final good u? We have: (a) technologies from n with home town m at unit cost $c_n^f/z_{m,nn}^f(u)$, (b) technologies from $i \neq n$ with home town m at unit cost $h_{ni}c_n^f/z_{m,ni}^f(u)$, (c) technologies from n with home town different than m at unit cost $\min_{s\neq m} h_{nn}c_n^f/z_{s,nn}^f(u)$, (d) technologies from $i \neq n$ with home town different than m at unit cost $\min_{s\neq m} h_{nn}h_{ni}c_n^f/z_{s,ni}^f(u)$. This implies that

$$p_{m,n}^f(u) = \min\left(\frac{c_n^f}{z_{m,nn}^f(u)}, \frac{h_{ni}c_n^f}{z_{m,ni}^f(u)}, \min_{s\neq m}\frac{h_{nn}c_n^f}{z_{s,nn}^f(u)}, \min_{i\neq n}\min_{s\neq m}\frac{h_{nn}h_{ni}c_n^f}{z_{s,ni}^f(u)}\right).$$

What are the different technologies available for town m for using intermediate good v? We have: (a) technologies from n with home town m at unit cost $c_n^g/z_{m,nn}^g(v)$, (b) technologies from $i \neq n$ with home town m at unit cost $h_{ni}c_n^g/z_{m,ni}^g(v)$, (c) technologies from n with home town different than m at unit cost

$$\min\left\{\min_{s\neq m}\frac{h_{nn}c_n^g}{z_{s,nn}^g(v)}, \min_{s\neq m}\frac{d_{nn}c_n^g}{z_{s,nn}^g(v)}\right\},$$

(d) technologies from $i \neq n$ with home town different than m at unit cost

$$\min\left\{\min_{i\neq n}\min_{s\neq m}\frac{h_{nn}h_{ni}c_n^g}{z_{s,ni}^g(v)}, \min_{i\neq n}\min_{s\neq m}\frac{d_{nn}h_{ni}c_n^g}{z_{s,ni}^g(v)}\right\},$$

(e) technologies from $i \neq n$ used in their home town in country i and imported to m at unit cost $\min_i d_{ni}c_i^g/z_{ii}^g(v)$, (f) technologies from i used in their home town in $l \neq n$ and imported to m at unit cost $\min_{i,l}\xi_{nli}/z_{li}^g(v)$, where $\xi_{nli} \equiv d_{nl}h_{li}c_l^g$. Given $d_{nn} < h_{nn}$, this implies that

$$p_{m,n}^g(v) = \min\left(\frac{c_n^g}{z_{m,nn}^g(v)}, \min_{i\neq n}\frac{h_{ni}c_n^g}{z_{m,ni}^g(v)}, \min_{s\neq m}\frac{d_{nn}c_n^g}{z_{s,nn}^g(v)}, \min_{i\neq n}\min_{s\neq m}\frac{d_{nn}h_{ni}c_n^g}{z_{s,ni}^g(v)}, \min_{i\neq n}\frac{d_{ni}c_i^g}{z_{ii}^g(v)}, \min_{i\neq n, l\neq n}\frac{\xi_{nli}}{z_{li}^g(v)}\right).$$

As in the case of a close economy, these results together with the assumption that productivities are independently drawn from the Fréchet distribution imply that the price indexes for final and intermediate goods are given respectively by

$$\left(\gamma^{-1}P_n^f\right)^{-\theta} = \frac{L_n\bar{T}_n}{M_n}(c_n^f)^{-\theta}(1+(M_n-1)h^{-\theta}) + \sum_{i\neq n}\frac{L_i\bar{T}_i}{M_n}(h_{ni}c_n^f)^{-\theta}(1+(M_n-1)h^{-\theta}),$$

and

$$\begin{aligned}\left(\gamma^{-1}P_n^g\right)^{-\theta} &= \frac{L_n\bar{T}_n}{M_n}(c_n^g)^{-\theta}(1+(M_n-1)d_{nn}^{-\theta}) + \\ &\sum_{i\neq n,l=n}\frac{L_i\bar{T}_i}{M_n}(h_{ni}c_n^g)^{-\theta}(1+(M_n-1)d_{nn}^{-\theta}) + \\ &\sum_{i\neq n,l=i} M_i\frac{L_i\bar{T}_i}{M_i}(d_{ni}c_i^g)^{-\theta} + \sum_{l\neq n,l\neq i} M_l\frac{L_i\bar{T}_i}{M_l}\xi_{nli}^{-\theta}.\end{aligned}$$

Using the definitions of ξ_{nli}, D_n and H_n, we get the result of equations (6) and (7).

Proof of Lemma 1. First, we rewrite (14) as follows,

$$Y_{gnn} = \frac{M_nT_nc_{gn}^{-\theta}\Psi'_n}{(\gamma_gP_{gn})^{-\theta}},$$

where

$$\Psi'_n = \left[D_n\eta w_nL_n + \sum_{j\neq n} d_{jn}^{-\theta}(\gamma_gP_n^g)^{-\theta}\,\eta w_jL_j\left(\gamma_gP_j^g\right)^{-\theta}\right].$$

Using the expression above for Y_{gnn} and (12), it is easy to get the following expression for real wage:

$$w_nP_{fn} = \widetilde{\gamma}(M_nT_n)^{(1+\eta)/\theta}H_n^{1/\theta}Y_{gnn}^{-\eta/\theta}\,(Y_{fnn}w_nL_n)^{-1/\theta}\,(\Psi'_n)^{\eta/\theta},$$

To obtain the expression of real wage, we rewrite (**??**) as

$$\Psi'_n = D_n\eta w_nL_n + \eta w_nL_n\sum_{j\neq n}\left(\frac{d_{jn}P_{gn}}{P_{gj}}\right)^{-\theta}\frac{w_jL_j}{w_nL_n}.$$

Then we use the gravity equation, (10) and $\sum_{j=1}^{N} X_{jn} = \eta w_n L_n$, to get

$$\Psi_n' = D_n \eta w_n L_n \left(\frac{\eta w_n L_n}{X_{nn}} \right),$$

and replacing on (**??**), we obtain (15).

Proof of Proposition 1. To analyze the gains from openness, we consider first the case in which MP is not possible. In the only trade case, $h_{ni} \to \infty$, for all $n \neq i$, then $X_{nn} \to \eta w_n L_n \left(c_n^g\right)^{-\theta} (\gamma P_n^g)^{-\theta} D_n T_n L_n$ and $\left(\gamma P_n^f\right)^{-\theta} \to H_n T_n L_n \left(c_n^f\right)^{-\theta}$. Therefore, the real wage is

$$\left(w_n P_n^f\right)^{Trade} = \tilde{\gamma} (T_n L_n)^{(1+\eta)/\theta} D_n^{\eta/\theta} H_n^{1/\theta} X_{nn} \eta w_n L_n{}^{-\eta/\theta}.$$

The gains from MP in country n, GMP_n, is the ratio between (15) and (**??**), which is the increase in the wage when a country goes from a situation in which MP is impossible to a situation with MP. In this case, GMP_n are:

$$GMP_n = \left(\frac{Y_{nn}^g}{\eta w_n L_n} \right)^{-\eta/\theta} \left(Y_{nn}^f w_n L_n \right)^{-1/\theta}.$$

In second place, we consider the case in which trade is not possible. When $d_{ni} \to \infty$, for all $n \neq i$, we have $Y_{nn}^g = T_n L_n \left(c_n^g\right)^{-\theta} D_n \eta w_n L_n (\gamma^g P_n^g)^{-\theta}$, and $(\gamma P_n^g)^{-\theta} = \left(c_n^f\right)^{-\theta} H_n \left(T_n L_n + \sum_{i \neq n} T_i L_i h_{ni}^{-\theta} \right)$. We define $T_f \equiv T_n L_n + \sum_{i \neq n} T_i L_i h_{ni}^{-\theta}$. Therefore in the only MP model, the real wage is:

$$\left(w_n P_n^f\right)^{MP} = \tilde{\gamma} (T_n L_n)^{\eta/\theta} D_n^{\eta/\theta} H_n^{1/\theta} T_f^{1/\theta} Y_{nn}^g \eta w_n L_n{}^{-\eta/\theta}.$$

The expression for Y_{nn}^f in (14) can be rearranged as

$$Y_{nn}^f w_n L_n = T_n L_n \left(c_n^f\right)^{-\theta} H_n T_f \left(c_n^f\right)^{-\theta} H_n = T_n L_n T_f,$$

so we can get an expression for T_f and replace it in (**??**) to obtain:

$$\left(w_n P_n^f\right)^{MP} = \widetilde{\gamma}(T_n L_n)^{(1+\eta)/\theta} D_n^{\eta/\theta} H_n^{1/\theta} \left(Y_{nn}^f w_n L_n\right)^{-1/\theta} Y_{nn}^g \eta w_n L_n{}^{-\eta/\theta}.$$

The ratio between (15) and (**??**) is the gains from trade, GT_n, which is the comparison between the real wage when there is only MP to the equilibrium with MP and trade. In this case these gains are:

$$GT_n = \left(\frac{X_{nn}}{\eta w_n L_n}\right)^{-\eta/\theta}.$$

It is easy to see that gains from openness, GO_n, which is the ratio between (15) and (5) is:

$$GO_n = \left(\frac{Y_{nn}^g}{\eta w_n L_n}\right)^{-\eta/\theta} \left(Y_{nn}^f w_n L_n\right)^{-1/\theta} \left(\frac{X_{nn}}{\eta w_n L_n}\right)^{-\eta/\theta}.$$

Then, $GO_n = GT \times GMP$.

B MP Data

Data on MP is from UNCTAD, Investment and Enterprise Program, FDI Statistics, FDI Country Profiles, published and unpublished data.[6] A foreign affiliate is defined in the data as a firm who has more than 10% of its shares owned by a foreigner. Most countries report magnitudes for majority-owned affiliates only (more than 50% of ownership).[7] The data refer to non-financial affiliates in all sectors with a few exceptions of countries that report data only on foreign affiliates in manufacturing.[8]

The UNCTAD measure of MP includes both local sales in n and exports to any other

[6]Unpublished data are available upon request at fdistat@unctad.org.
[7]Majority-owned affiliates are the largest part of the total number of foreign affiliates in a host economy.
[8]The exceptions are Italy and United Kingdom.

country, including the home country i. Out of 342 possible country-pairs, data are available for 219 country-pairs. We impute missing values by running the following OLS regression

$$\log \frac{Y_{ni}}{w_n L_n} = \beta_d \log d_{ni} + \beta_c b_{ni} + \beta_l l_{ni} + S_i + D_n + e_{ni},$$

where Y_{ni} is gross production of affiliates from i in n, $w_n L_n$ is GDP in country n, d_{ni} is geographical distance between i and n, b_{ni} (l_{ni}) is a dummy equal to one if i and n share a border (language), and zero otherwise, and S_i and D_n are two sets of country fixed effects, for source and destination country, respectively. All variables are averages over the period 1996-2001. The variable GDP is in current dollars, from the World Development Indicators, and the variables for distance, common border and language are from CEPII.

C Additional tables

Table 4: Data: Summary.

	Domestic MP shares final	intermediate	Domestic trade shares	Equipped labor	$RealGDP$ p.c.	R&D employment	Number of towns
Australia	0.21	0.54	0.64	0.06	0.86	0.79	4
Austria	0.30	0.62	0.38	0.02	0.94	0.57	2
Belgium	0.27	0.38	0.03	0.03	0.99	0.79	2
Canada	0.28	0.52	0.44	0.11	0.81	0.74	6
Denmark	0.32	0.79	0.36	0.02	0.91	0.75	1
Spain	0.48	0.78	0.65	0.08	0.96	0.43	5
Finland	0.58	0.81	0.59	0.02	0.82	1.48	1
France	0.39	0.75	0.59	0.15	0.94	0.73	8
United Kingdom	0.32	0.68	0.55	0.16	0.90	0.63	9
Germany	0.45	0.76	0.60	0.26	0.81	0.72	14
Greece	0.31	0.84	0.54	0.02	0.77	0.33	2
Italy	0.59	0.89	0.70	0.13	1.11	0.34	7
Japan	0.56	0.95	0.87	0.51	0.70	1.12	26
Netherlands	0.21	0.40	0.18	0.04	0.94	0.60	3
Norway	0.28	0.77	0.52	0.02	0.80	0.92	1
New Zealand	0.12	0.24	0.57	0.01	0.69	0.61	1
Portugal	0.31	0.52	0.53	0.02	0.92	0.35	1
Sweden	0.41	0.67	0.52	0.03	0.77	1.06	2
United States	0.37	0.80	0.77	1.00	1.00	1.00	51

Domestic MP in the final good sector is calculated as share of GDP. Domestic MP in the intermediate good sector is calculated as share of gross production in manufacturing. Domestic trade in manufacturing is calculated as share of absorption in manufacturing. $RGDPL$ is calculated as PPP- adjusted real GDP per capita times population, divided by equipped labor. R%D employment is shown as share of total employment. Number of towns is calculated using $M_n = L_n/\overline{L}$ where $\overline{L} = L_{USA}/M_{USA}$. Equipped labor, $RGDPL$, and R&D employment are shown relative to the magnitudes for the United States. Data in columns (1)-(6) are average over 1996-2001.

Table 5: Calibration's results. All countries.

	Real Wage (relative to U.S.)				
	No domestic frictions		Domestic frictions		Data
	isol.	*GO*	isol.	*GO*	
Australia	0.50	0.58	0.74	0.85	0.86
Austria	0.39	0.43	0.67	0.75	0.94
Belgium	0.42	0.61	0.73	1.06	0.99
Canada	0.54	0.62	0.74	0.84	0.81
Denmark	0.35	0.38	0.71	0.78	0.91
Spain	0.45	0.44	0.64	0.62	0.96
Finland	0.41	0.39	0.84	0.80	0.82
France	0.58	0.59	0.75	0.76	0.94
United Kingdom	0.58	0.62	0.73	0.78	0.90
Germany	0.67	0.66	0.78	0.77	0.81
Greece	0.34	0.36	0.58	0.62	0.77
Italy	0.46	0.43	0.61	0.57	1.11
Japan	0.87	0.79	0.93	0.85	0.70
Netherlands	0.43	0.57	0.68	0.89	0.94
Norway	0.37	0.40	0.75	0.81	0.80
New Zealand	0.33	0.45	0.68	0.92	0.69
Portugal	0.29	0.31	0.59	0.64	0.92
Sweden	0.45	0.46	0.78	0.81	0.77
United States	1.00	1.00	1.00	1.00	1.00

Calibration with $\theta = 6$.